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Environment, Safety, and Health

Volume II

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18.3 Pressure Testing

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Recommended for approval by the ES&H Working Group

Approved by: Charles Borzileri
Pressure Safety Manager

New document or new requirements

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* Minor revision

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Pressure Testing

1.0 Introduction

Pressure tests are performed to ensure safety, reliability, and leak tightness.

This document contains general testing requirements for LLNL documented pressure systems and vessels, as well as specific requirements for in-place pressure testing with gas and liquid. Appendix A contains definitions of pressure terms used in this document. Individuals who work with pressure vessels and systems shall adhere to the requirements in this document unless otherwise specified.

2.0 Hazards

The hazards presented to personnel, equipment, facilities, the public, or the environment because of inadequately designed or improperly operated pressure systems include blast effects, shrapnel, fluid jets, release of toxic or asphyxiant materials, contamination, equipment damage, personnel injury, and death.

3.0 Controls for Testing and Inspecting Pressure Vessels and Systems

Whenever practical, send pressure vessels and systems to the Mechanical Engineering (ME) High-Pressure Test Facility, Bldg. 343, for pressure testing. If this is not practical, test the equipment in accordance with the requirements in either Section 3.7 or 3.8 in this document. All pressure tests shall be conducted remotely and be observed (or conducted) and certified by an LLNL pressure inspector. See Fig. 1 for the relationships of test and retest pressures to the Maximum Allowable Working Pressure (MAWP) and Maximum Operating Pressure (MOP).

The pressure inspector who observes or conducts the test will verify that required documentation is signed, the successful pressure test has been completed, and the system or vessel is properly labeled before use. The pressure inspector will complete Form LL-3586, based on observations and tests results, and send it to the pressure safety manager. He/she also will attach an LLNL Pressure Tested Label (Fig. 2) to pressure vessels and systems that have been successfully tested.

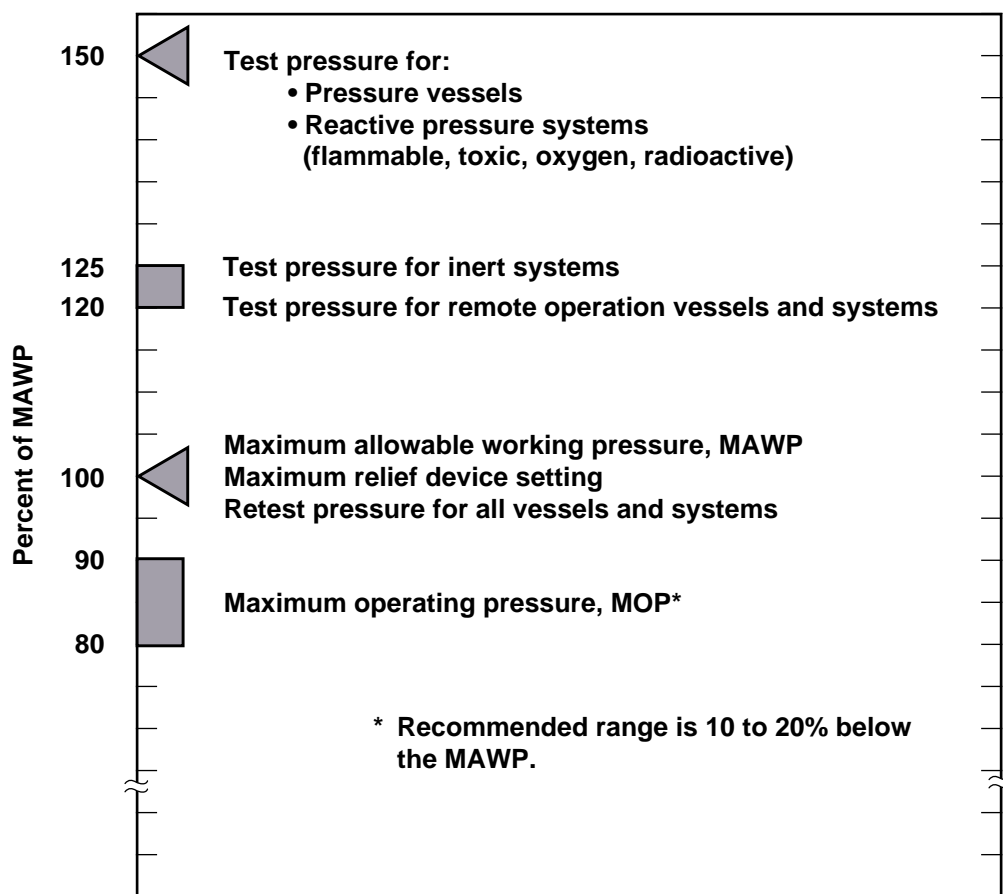


Figure 1. Relationships between test pressures, the MAWP, and the MOP.

LLNL PRESSURE TESTED FOR MANNED AREA	
ASSY.	
SAFETY NOTE	
M.A.W.P.	PSIG.
FLUID	
TEMP.	TO °F
REMARKS	
TEST NO.	T.R.
EXPIRATION DATE	
BY	DATE

Figure 2. LLNL pressure tested for manned area label (silver on black).

3.1 Pressure Testing

All LLNL-fabricated pressure vessels or systems that require documentation shall be pressure tested remotely prior to operation. Once tested, an LLNL pressure-tested label shall be attached to the equipment.

All LLNL-designed pressure vessels or systems that require documentation and that are fabricated offsite shall be pressure tested remotely prior to operation. If the vendor is to test the vessel or system, the testing specification shall be included in the purchase order. Certified test results shall be supplied with the hardware. When the test results are accepted or the hardware is tested at LLNL, an LLNL pressure-tested label shall be attached to the equipment.

Responsible Individuals shall maintain documented and labeled pressure vessels and systems and their integral pressure-relief devices. A qualified, independent LLNL pressure inspector shall inspect the equipment every 3 years as recommended in the National Board Inspection Code (NBIC).

3.2 Pressure Vessels

Test pressure vessels in accordance with the requirements in this document using an inert fluid. Initially test manned-area vessels at 150% of their MAWP or at the test pressure specified in the Engineering Safety Note (ESN). Take appropriate diameter measurements, accurate to within 0.001 in. (0.025 mm), both before and after testing to show that detectable plastic yielding has not occurred during pressurization.

Remote-operation vessels should be tested at a pressure that is consistent with the functional reliability required (usually 125% of the MAWP). If it is determined that a pressure test is not practical, then inspect the vessel ultrasonically. In addition, check the vessel for surface cracks by the magnetic particle test or (for nonmagnetic vessels) the fluorescent penetrant test.

3.3 Pressure Systems

Test nonhazardous liquid, inert gas, and compressed air systems at 125% of their MAWP using an inert fluid.

Test toxic, oxygen, radioactive, and flammable fluid systems at 150% of their MAWP using an inert fluid.

3.4 Leak Checking

Leak check pressure vessels and systems at their MAWP, as required, after successful pressure testing. Gross leakage can be detected by observing the drop in pressure on the test gauge during pressure testing, and can be pinpointed with leak-detection fluid. Small leaks can be located with commercial leak detectors.

CAUTION

- If you detect a leak while pressure testing a documented (ESN, ASME, DOT, or unmodified commercial hardware) manned-area vessel or system and decide to repair it before completing the test, reduce the pressure as low as possible (not over one-half the immediately preceding test pressure) for locating the leak.
- Do not use an open flame for leak checking.
- Leak check remote-operation vessels and systems remotely. Manned-area leak checking of successfully pressure-tested, remote-operation vessels and systems is limited to a maximum of 20% of the test pressure.
- Never attempt to repair a system or vessel when it is pressurized, unless specifically authorized by a level B OSP (refer to Document 2.2, "Managing ES&H for LLNL Work," in the *ES&H Manual*
- Do not leak check undocumented vessels or systems in a manned-area at pressures higher than 20% of the test pressure or at a previously achieved pressure, whichever is lower.

3.5 Inspection

Inspection intervals for pressure vessels will be determined using the in-service inspection criteria in the NBIC. Depending on the type of vessel service, the intervals may range from two years to a maximum of 10 years. Relief devices on pressure vessels will be inspected every 3 years. In addition, pressure systems and vessels will be reinspected before reuse whenever they are disassembled/moved or redesigned, or when the application changes, even if the working pressure is reduced. If the vessel or system has been damaged or modified, it will be retested. This determination shall be made by a responsible designer and a pressure inspector.

Pressure inspection is done by a pressure inspector and findings are recorded on Form LL-3586. Upon completion of inspection, the Responsible Individual signs the form and sends it to LLNL Pressure Safety where it becomes a permanent record.

If an inspection or retest is due on a system or vessel that is currently not in use, it can be considered "stored in place". The pressure inspector completes form LL-6278, and the responsible individual will sign it. By doing so, the individual agrees that before the equipment is put back into service, the system or vessel shall be inspected and/or tested and tagged with a new LLNL pressure tested label by an LLNL pressure inspector.

DOT compressed gas cylinders are normally retested every 5 years. The gas supply vendor is responsible to retest and re stamp the cylinders before returning them to the user (LLNL). Portable trailer banks and stationary DOT cylinders which have previously been filled in place will be sent back to the vendor for retest if the last test date exceeds five years. The industrial gas section of procurement and materials will be the custodian of these cylinders.

3.6 In-place Pressure Testing

If it is impractical to pressure test a vessel or system at the ME High-Pressure Test Facility, pressure test it in place using either the procedure in Section 3.7 (gas) or Section 3.8 (liquid).

3.6.1 Responsibilities

All workers and organizations shall refer to Document 2.1, "Laboratory and ES&H Policies, General Worker Responsibilities, and Integrated Safety Management," in the *ES&H Manual* for a list of general responsibilities. This section describes specific responsibilities of LLNL organizations and workers who have key safety roles.

The responsible designer shall prepare the required test procedure, direct testing personnel, and witness in-place pressure testing of vessels and systems for which he/she is responsible.

The Responsible Individual is similarly responsible for in-place retesting of pressure equipment for which he/she is responsible.

Although others may be designated to observe and direct testing or retesting, responsibility for safe conduct of the test and safe functioning of tested pressure equipment cannot be delegated.

3.6.2 Test Procedure

A test procedure is required for every pressure test conducted in the field. See Document 3.4, "Preparation of Work Procedures," in the *ES&H Manual* for the development and approval of test procedures. If only a safety manifold or equivalent (see Figs. 3 and Fig. 4) is employed, use the applicable standard procedure for pressure testing in place.

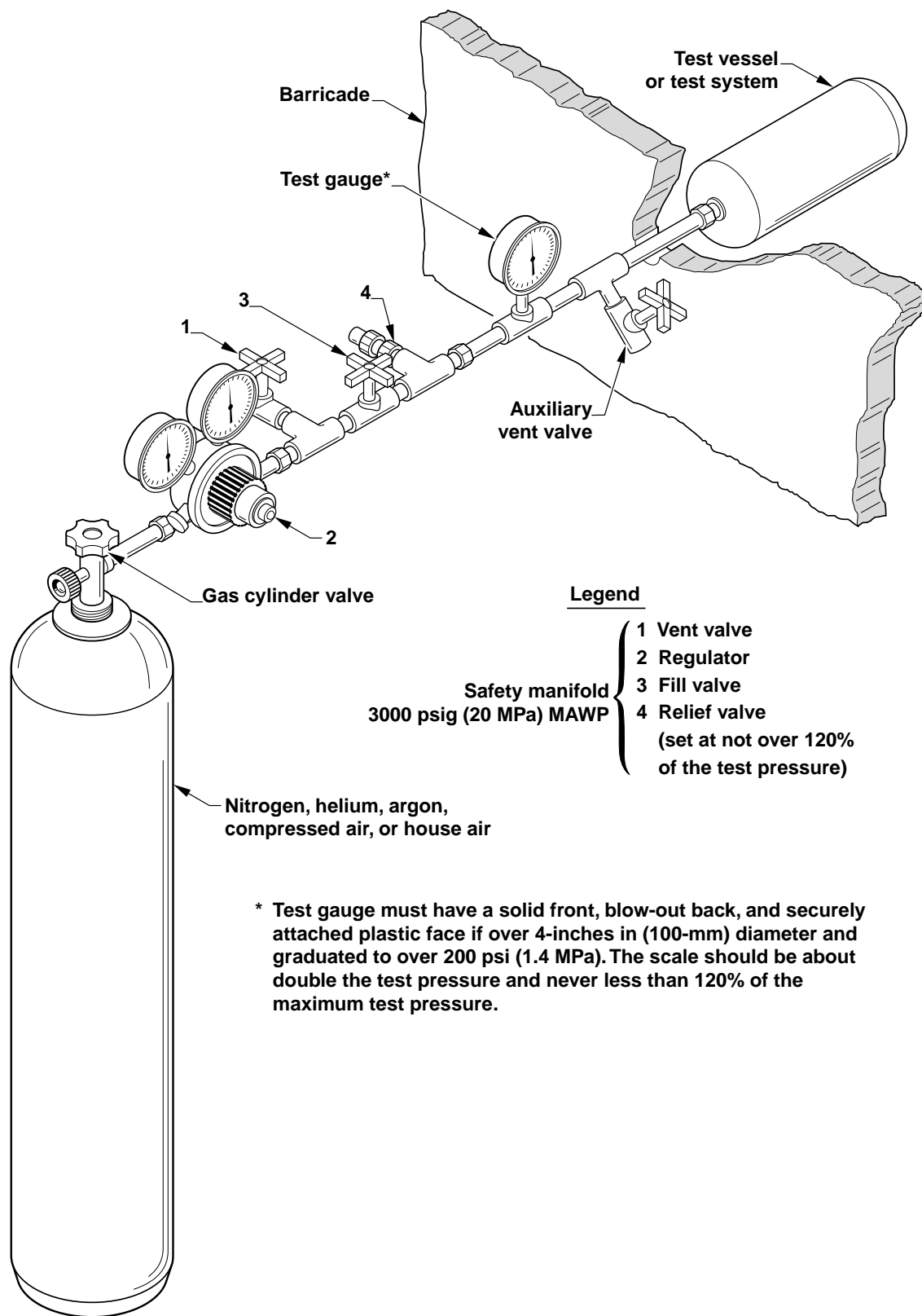


Figure 3. Setup for pressure testing with gas.

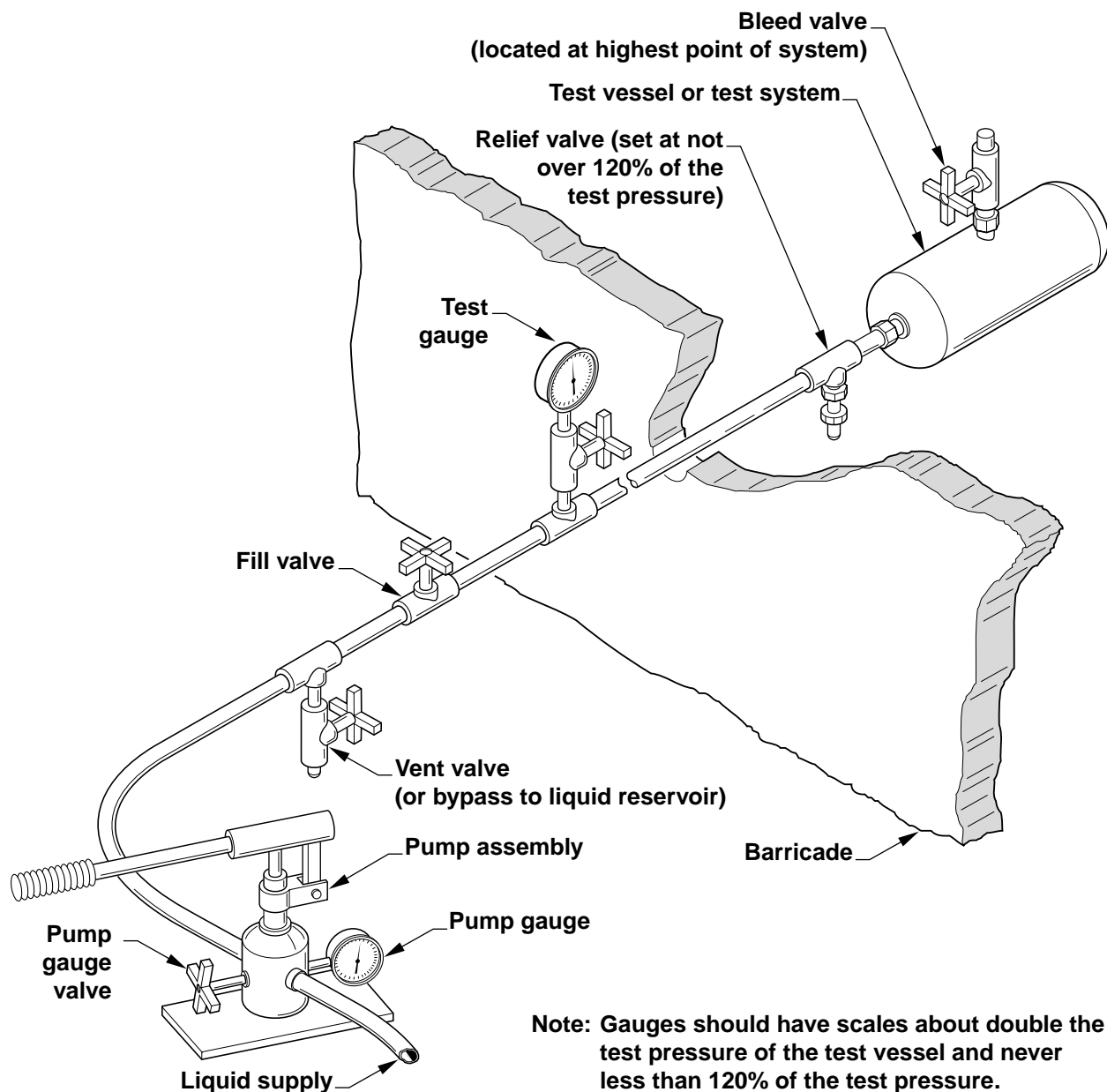


Figure 4. Setup for pressure testing with liquid.

Because the requirement that testing be conducted in place is usually apparent to the responsible designer, the test procedure should normally be included in or appended to the ESN. Refer to Facility Safety Plan 343 for testing in the ME High-Pressure Test Facility where separate test procedures are not required.

3.6.3 Test Procedure Approval

Procedures for in-place testing of vessels and systems shall be signed by:

- The responsible designer.
- A pressure consultant who maintains a complete file of all in-place testing procedures that he/she approves.
- The area ES&H Team if oxygen or toxic, flammable, or radioactive material is involved.

The building coordinator or area supervisor shall be advised of pressure tests planned for his/her facility.

3.6.4 Test Personnel

The pressure test shall be observed (if not conducted) by a pressure inspector. The responsible designer (or responsible user) shall have a pressure installer (or pressure operator) set up the test.

3.6.5 Precautions

- Pressure testing with gas is more dangerous than with liquid. So test with liquid whenever possible. See the procedures in Section 3.7 (testing with gas) Section 3.8 (testing with liquid).
- If practical, fill the voids in a test vessel with solids, such as balls or filler rods. Slot the inside of vessel fittings so that the balls cannot stop fluid flow, or groove the ends of filler rods for the same reason. Filling the voids reduces the available energy in case of violent vessel failure.
- Barricade the equipment being tested, or shield controls and operators, and evacuate all unauthorized personnel. Selective shielding of possible projectiles or fragments and liquid jets should be considered. Refer to "ME Design Safety Standards" for the design of personnel and equipment shields.
- Borrow "Danger—High-Pressure Test in Progress—Keep Out" signs from Maintenance, Bldg. 511, or from the ME High-Pressure Test Facility, Bldg. 343, and post them at all approaches to the test area.
- To protect the equipment being tested from over pressurization, a relief valve set at no more than 120% of the test pressure shall be used. Following the test, remove this relief device and replace with the system relief device.

- For in-place testing with liquids, remove all air from both the testing system and the equipment to be tested. Compressed air would expand violently in case of vessel failure. Spongy action of pumping equipment usually indicates the presence of trapped gas.

3.7 Standard Procedure for In-place Pressure Testing with Gas

This procedure template may be used as guidance for preparing an actual procedure for conducting low- and intermediate-pressure in-place gas tests with the safety manifold shown in Fig. 3. Safety manifolds for gas testing at up to 3000 psig (21 MPa gauge) are available from the Maintenance Mechanics Instrument Shop in Bldg. 511 or the ME High-Pressure Test Facility in Bldg. 343. See Document 3.4 for the development and approval of test procedures.

3.7.1 Pretest Procedure

The following actions shall be taken before actual pressure testing is started (refer to Fig. 3):

1. Take the approved test procedure to Bldg. 511 or Bldg. 343, where an LLNL pressure inspector will issue the appropriate safety manifold.
2. Barricade the test vessel or system, or install personnel shielding.
3. Attach the safety manifold to the test vessel or system with adapters and tubing rated at or above the testing pressure.
4. Install a pressure-relief device with adequate total-flow capacity, set at not over 120% of the required test pressure.
5. Post warning signs, "Danger—High-Pressure Test in Progress—Keep Out," at all approaches to the test area.
6. Back off the regulator adjusting screw (2) (counterclockwise), open the vent valve (1), close the fill valve (3), and connect the regulator to the supported compressed-gas cylinder.
7. Have the test system checked by a pressure inspector who is authorized to prohibit testing if, in his/her opinion, the test setup is unsafe, the system has not been properly identified, or not all of the precautions in this procedure have been observed.

3.7.2 Test Procedure

Persons not directly involved in the test shall leave the area. The responsible designer or Responsible Individual (or a designated alternate) and a pressure inspector shall witness the test, which shall consist of the following steps (refer to Fig. 3):

1. Measure and record test vessel dimensions as indicated on the test procedure. (Omit this step and step 13 below when only a system is being tested.)
2. With the fill valve (3) closed, the vent valve (1) open, and regulator adjusting screw (2) backed off (counterclockwise), slowly open the gas cylinder valve.
3. Close the vent valve (1).
4. Turn the regulator adjusting screw (2) until the regulator low-side pressure gauge indicates about 110% of the test pressure.
5. Open and close the vent valve (1) as required to confirm an accurate regulator setting; then close the vent valve (1).
6. Close the gas cylinder valve, open the fill valve (3), and confirm by the low-side regulator gauge reading that the flow path is open to the test vessel or system. Then close the fill valve (3) and slowly open the gas cylinder valve.
7. Slowly open the fill valve (3).
8. When the test vessel or system has reached the specified test pressure, close the fill valve (3) and the gas cylinder valve, and open the vent valve (1).
9. Periodically check the test gauge for signs of vessel or system leakage during the 30-min (or otherwise specified) pressure-hold time.
10. If unacceptable leakage is observed (based upon test procedure requirements), open the auxiliary vent valve to drop the system to the lowest possible pressure for locating the leak. In the interest of safety, never leak check at a higher pressure than necessary. This leak-test pressure shall not exceed one-half the immediately preceding pressure applied to the system. Locate the leak, drop the pressure to zero, repair the leak, and repeat steps 1 through 9.

CAUTION

The vessel or system has not yet been proven safe for manned-area operation. If leakage is minor, complete the pressure test remotely and leak check later (after step 13) at a pressure not exceeding the MAWP that you have, by then, established as safe. Reduce the pressure to zero before repairing any leaks.

If a leak is detected past a seal of a test vessel, as distinguished from a minor fitting leak, repair as required and repeat the entire pressure test.

11. If the leak rate is acceptable, hold the test pressure for the required time, then release the pressure by opening the fill valve (3) or the auxiliary vent valve.
12. Verify that the gas cylinder valve is closed and that both regulator gauges read zero.
13. After 30 min, remeasure and record the diameters to confirm that the vessel has not plastically yielded.

3.7.3 Leak Checking

After pressure testing, leak check (as required by the ESN) the manned-area gas vessel or system at its MAWP.

3.7.4 Labeling

The pressure inspector will label (Fig. 2) the tested equipment, complete the Pressure Test Record (Form LL-3586), and send it to LLNL pressure safety manager.

3.8 Standard Procedure for In-place Pressure Testing with Liquid

The following procedure template may be used as guidance for preparing an actual procedure. See Document 3.4 for the development and approval of test procedures.

3.8.1 Pretest Procedure

Pretest Procedure. The procedure below may be used for conducting in-place hydrostatic pressure tests; it shall be performed prior to starting the actual test (refer to Fig. 4).

1. Post "Danger—High-Pressure Test in Progress—Keep Out" signs at all approaches to the test area.
2. Fill the pump gauge and test gauge with testing liquid, close the pump gauge valve, close the test gauge valve, and assemble as shown in Fig. 4 using components rated at or above the test pressure.
3. Remove any test system gauges, or fill them with liquid, and plug openings as required. **CAUTION:** If gas pressure is required to operate any test system valves or components, the responsible designer (or Responsible Individual) shall include instructions for their operation in the pretest or test procedure and shall be present whenever such valves or components are operated. These valves or components shall be tagged with their rated MAWP before being operated. To have the equipment tagged, contact the LLNL pressure inspector.

4. Close the vent valve, open both the fill valve and bleed valve, then fill the system with liquid using (or through) the pump.
5. Close the bleed valve, open both the pump gauge valve and test gauge valve, then close the fill valve.

3.8.2 Test Procedure

Persons not directly involved in the test shall leave the area. The responsible designer or Responsible Individual (or a designated alternate) and a pressure inspector shall witness the test, which shall consist of the following steps (refer to Fig. 4):

1. Measure and record the diameters at mid-point and quarter-point of cylindrical test vessels (at pole and waist of spherical vessels). (Omit this step and step 7 below when only a system is being tested.)
2. Open the fill valve and slowly pump to the test pressure.
3. Close the fill valve.
4. Periodically check the test gauge for signs of vessel leakage during the 30-min (or otherwise specified) pressure-hold time.
5. If unacceptable leakage is observed (based upon test procedure requirements), open both the vent valve and fill valve to drop the system pressure to zero, then locate and repair the leak. Remove all air from the system, close the vent valve, then slowly pump again to the test pressure and hold for the required time.
6. If the leak rate is acceptable, hold the test pressure for the required time by opening the fill valve, pumping as required, and then closing the fill valve. Then open the vent valve, fill valve, and bleed valve to release the pressure; drain the liquid from the system.
7. After 30 min, remeasure and record the diameters to confirm that the vessel has not plastically yielded.

3.8.3 Leak Checking

After successful pressure testing, leak check (as required by the ESN) the manned-area gas vessel or system at its MAWP. Leak check liquid vessels and systems to the extent necessary to assure the functional reliability required, as specified on the ESN.

3.8.4 Labeling

The pressure inspector will label (Fig. 2) the tested vessel or system, enter the required information on the Pressure Test Record (Form LL-3586), and send it to the LLNL pressure safety manager.

4.0 Work Standards

4.1 Primary Standards

ANSI/B 31.1, Power Piping Code, ASME Code for Pressure Piping, 1995.

ASME Boiler and Pressure Vessel Codes, Section VIII, Div. 1 and 2 "Rules for Construction of Pressure Vessels," 1998.

8 CCF § 450–560, "Unfired Pressure Vessel Safety Orders (propane tanks, Air Receivers)."

29 CFR 1910.101, "Compressed Gases General Requirements."

29 CFR 1910.103, "Hydrogen."

29 CFR 1910.110, "Storage and Handling of Liquified Petroleum Gases."

29 CFR 1910.132. Subpart I, "Personal Protective Equipment."

29 CFR 1910.146, "Permit-required Confined Spaces."

29 CFR 1910, Subpart J, "General Environmental Controls."

49 CFR 100–199, "Research and Special Programs Administration, DOT (off-site)."

NFPA 45, *Laboratories Using Chemicals*.

NFPA 51, *Welding, Cutting and Allied Processes*.

UCRL-AR-128970, *LLNL Pressure Safety Standard*.

4.2 Secondary Standards

ACGIH TLVs and BEIs: Threshold Limit Values for Chemical Substances and Physical Agents.

CGA (Compressed Gas Association) P-12, "Safe Handling of Cryogens." CGA (Compressed Gas Association) S-1.2, Pressure Relief Devices Standards. Part 2 - "Large and Portable Tanks for Compressed Gasses."

CGA (Compressed Gas Association) S-1.3, Pressure Relief Devices Standards. Part 3 - "Compressed Gas Stationary Storage Containers."

Public Law 91-596 § (5)(a)(1), OSHA Act of 1970.

5.0 Resources for More Information

5.1 Contacts

For additional information about this document, contact the LLNL Pressure safety manager or the ME High-Pressure Test Facility.

5.2 Lessons Learned

For lessons learned applicable to pressure vessels and systems, refer to the following web site:

http://www.llnl.gov/llnl_only/es_and_h/lessons/lessons.shtml

5.3 Other Sources

DOE Order 440.1A, "Worker Protection Management for DOE Federal and Contractor Employees," Attachment 2, "Contractor Requirement Document," Sections 1-11, 13-18 (delete item 18.a), 19 (delete item 19.d.3) and 22.

National Board Inspection Code (1998 edition).

Appendix A

Terms and Definitions

Engineering safety note (ESN) An engineering safety note is a management-approved (by division leader or higher) document that describes the anticipated hazards associated with a piece of equipment or a process. It describes the responsible individual's approach, analysis, and rationale used to assure the design safety of the equipment, system, or process. An ESN does not have to be prepared by a member of the Engineering directorate as long as the individual is technically qualified to prepare the ESN.

Mechanical Engineering and Electronics Engineering Safety Notes are assigned a safety note number by the Engineering Records Center where a copy is kept on file. The designations for safety notes are as follows:

MESN = Mechanical Engineering Safety Note (signed by an ME Division Leader)

EESN = Electrical Engineering Safety Note (signed by an EE Division Leader)

LLSN = LLNL Safety Note (signed by a non-Engineering Division Leader)

The LLSN designation was established to permit institutional (non-Engineering Directorate) safety notes to be assigned a document number by the Engineering Records Center and archived there (optional).

Engineering safety note equivalent A file or drawing that includes properly approved design and additional information contained in an ESN.

High pressure Gas pressures greater than 21 MPa gauge, (3000 psig); liquid pressures greater than 35 MPa gauge (5000 psig).

Intermediate pressure Gas pressure from 1 to 21 MPa gauge (150 to 3000 psig); liquid pressure from 10 to 35 MPa gauge (1500 to 5000 psig).

Leak test or check A pressure or vacuum test to determine the existence, rate, and/or location of a leak.

Low pressure	Gas pressures less than 1 MPa gauge (150 psig); liquid pressures less than 10 MPa gauge (1500 psig).
Manned-area vessels / systems	Pressurized vessels or systems approved for operation within specified limits and with personnel present.
Maximum allowable working pressure (MAWP)	The maximum pressure at which a vessel or system is designed to operate safely. This is also the basis for all pressure testing. Working pressure, rated pressure, service pressure, and design pressure are the same as the maximum allowable working pressure. <i>Do not exceed this pressure when setting vessel or system pressure-relief devices.</i>
Maximum operating pressure (MOP)	The maximum pressure at which a vessel or system is normally operated—usually 10 to 20% below the MAWP.
Pressure system	An assembly of pressure components that performs an intended function.
Pressure test	A test that ensures <ul style="list-style-type: none"> • A vessel or system will not fail or permanently deform. • The vessel or system will operate reliably at a specified pressure.
Pressure vessel	A relatively high-volume pressure component (such as a spherical or cylindrical container) that has a cross section larger than the associated pipe or tubing.
Remote operation	A pressure operation that shall not be conducted with personnel present. The equipment shall be installed in test cells, behind certified barricades, or be operated from a safe location. Unless otherwise specified in an ESN, manned-area operations of a remote operation vessel or system are limited to a maximum pressure of 20 percent of the previously attained MAWP or test pressure.